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THE CONCENTRATION OF LARVAL COD AND ITS PREY IN THE ZONE OF A HYDROGRAPHIC FRONT

by

Peter Munk

Danish Institute for Fisheries Research
Charlottenlund Castle
DK-2920 Charlottenlund
Denmark

(ci Gadus morhua cc)

ABSTRACT

A series of field investigations, directed at cod larvae, was carried out during May 1992 to 1994 at the shelf slope of the Norwegian Trench (Skagerrak and North Sea). During the surveys we repeatedly observed peak abundance of cod larvae in the vicinity of a hydrographic front. Our observations suggest a tight coupling between the frontal zone formation and the biological productivity of the area.

During the investigation in 1994, we carried out a detailed study on the temporal and spatial variation in hydrography and biology in the frontal zone. A cross-frontal transect was passed six times during a three day period, followed by a revisit another three days later. The frontal zone was observed at the shelf slope, distinguished by declining pycnolines and the transition from salinity-stratified to salinity-mixed water masses. The current pattern changed markedly when passing the front. A distinct concentration of cod larvae was found near the front, in off-shelf direction the decline from maximal concentration (1-2 m^{-2}) to almost zero took place within a distance of about 15 km. The prominent peak in abundance at the front was observed for other macroplankters (interpreted from acoustics) and for copepods as well.

The characteristics of hydrography and biology remained basically the same during the six days of transect observations. The zone was found at the same geographical position and the distribution of organisms was in all cases strongly related to the hydrography.

INTRODUCTION

The spawning areas of North-Atlantic cod are found either in the neighbourhood of offshore banks (e.g. Browns Bank [Hurley & Campana 1989] and Georges Bank [Lough 1984]) or at specific coastal areas (e.g. Lofoten area [Ellertsen et al. 1981]) whereas the nursery areas of cod larvae and juveniles are observed above the shelf slopes, at the shelf break (Campana et al. 1989, Ellertsen et al. 1989, Lough 1984). At the shelf break, coastal water masses meet water of oceanic origin and here hydrographic fronts might be established (Moors et al. 1978). The distributional observations indicate that both the spawning areas and the nursery areas are linked to specific hydrographical characteristics. This potential linkage has been studied in detail during a research programme carried out by fishery institutes from Norway, Sweden and Denmark. The programme was focused on the nursery areas of cod in the northeastern North Sea and the Skagerrak, and a series of multidisciplinary surveys were carried out in May, 1992, 1993 and 1994.

The findings of the programme show a strong connexion between hydrography and distributional patterns of cod. The basic observations from the 1992 investigation are described in Munk et. al. 1995. In the present paper a part of the observations during 1994 on the nursery areas of cod will be described. During the study of 1994 special emphasis was given to a specific cross-frontal transect with the prime goal of evaluating the temporal variation in frontal position and plankton distribution.

MATERIALS AND METHODS

The transect followed 6°40'E between 57°30N and 56°20'N, across the shelf slope from 150 m to 38 m water depth (Fig. 1). The transect was passed seven times in the period May 11 to 17, 1994, it was passed every 12 hours during the first 3 days and then revisited another 3 days later.

Current profiles (ADCP, Research Devel. Coop.) and profiles of acoustic reflection (Echo-sounder 38 kHz, Simrad EK400) were measured continuously during all passes of the transect. CTD's, and sampling of plankton was carried out at different frequencies during each of the passes (10, 5 or 3 nm distance between stations).

Salinity and temperature were profiled (0.5 m depth intervals) using a Neil Brown Mark III CTD. Zooplankton were collected by a submersible pump (1.2 m^3 min^{-1}) equipped with a 30 μm conical net. When sampling it was raised from seabed to surface at a speed of 10 m min^{-1}. Zooplankton were preserved in 4% formalin. Larval/juvenile fish were sampled using a ring net of 2 m diameter. The basic design of the gear is illustrated in Munk (1993).

The gear has a two-legged, 10 m long bridle and is equipped with a 13 m long black net of 1.6 mm mesh size. At the station the gear was towed in an oblique haul sampling the water column to 5 m above the bottom. The gear was deployed and retrieved at wire-speeds of 25 and 15 m min^{-1}, respectively, while speed of ship was kept at 1.5 m s^{-1}. The volume of water filtered was estimated using a calibrated flowmeter in the centre of the net opening. All fish were preserved in 96% ethanol and were later identified to species and measured within 1 mm length intervals (standard length).

RESULTS

The observations along the transect will be illustrated by the data from Pass 1 and Pass 3, both of which with full coverage of cod abundance (Figs. 2 and 3).

Salinity

The salinity was mixed to the bottom at shallow waters (<50 m) whereas stratification with respect to salinity was observed further off-shelf (Figs. 2 and 3). The upper 15 m of the water column was mixed at all positions and the surface salinity showed a maximum in the transition zone between the mixed and stratified part, and this maximum (which is identified as the centre of the hydrographic front) had a relatively fixed position during the course of the study. Figure 4 illustrates the changes in surface salinity during transect passes, apparently the front did not move significantly during the first 3 days of observation. At the revisit 3 days later, however, the salinity maximum was found a few miles further off-shelf.

Temperature

The upper 10 meters was also mixed with respect to temperature, but below this depth the water was stratified along the entire transect (Figs. 2 and 3). The temperature profiles illustrate an upwelling of colder water masses along the shelf slope and upwards into the water column (at 50 m bottom depth).

Water density

The calculated water density illustrates the stratification of the watermasses, with declining pycnolines in a zone between isobaths of 40 and 60 m.

Currents

The current direction and velocity is illustrated for water depths of 15, 30, 45, 60 and 75 m in Figs 2 and 3. Off-shelf, at bottom depths > 60 m, the currents were easterly at about 0.25 m s^{-1}. At the isobath of 60 m the currents changed markedly, the direction changed 90 to 180 degrees within a short distance, and at a specific position (at 57°02'N) the current velocity decreased to almost zero. This position coincided with the position of maximal surface salinity. The current measurements include tidal influence, thus measurements varied somewhat from pass to pass, however, basically the current patterns were as illustrated for Pass 1 and 3.

Cod larvae

Cod larvae were sampled at densities up to 2 m^{-2}. The maximal densities were observed at a specific sampling position close to 57°N (Figs 2 and 3), near the site where dramatic hydrographic changes takes place, as described above. In the direction off-shelf from this position, the density of cod declined abruptly, from maximal density to almost zero within a distance of 15 km. The decline in density in the other direction was much more gradual. Larval sizes were in the range of 9 to 30 mm with very little trend in the spatial variation of larval mean size.

Macroplankton

The acoustic reflection is illustrated in Figure 5 for Pass 3. Un-quantified findings of crustacean plankton in the 2 meter ring net indicate that the acoustic measurements are related to macroplankton distribution, and the measurements are here assumed to describe macroplankton distribution. A night and a day profile illustrate the repeatedly observed difference between night and day distribution. In both cases it is evident that the abundance increased markedly at the 57°N position where hydrography showed special characteristics and where cod larvae peaked in abundance.

Copepods

The abundance of to species of copepods *Calanus finmarchicus* and *Pseudocalanus elongatus* is illustrated for Pass 6 in Figure 5. While *Calanus* showed maximal density at the surface sampling position at the most northern station, another peak in abundance was indicated at the 57°N position. The *Pseudocalanus* showed a peak in abundance at 20 m depth at the 57°N position.

DISCUSSION

The findings of the study in May 1994 are in accordance with the observations made in May 1992 at the same locality (Munk et al. 1995). The present study gives further insight into cross-frontal variation - on the spatial and the temporal scale.

Spatially, the fine-grained sampling across the front illustrate how abruptly changes in parameters might take place. The changes in biology always coincide with changes in hydrography. Thus, intermediate-scale physical processes obviously have a significant effect on plankton dynamics in the area. The distinctness of peaks in fish larval and crustacean distribution indicate that the influence of physical processes is not (only) indirect, by introduction of nutrients and enhancement of algal productivity, but also direct by physical forcing. The drastic changes in current pattern, when transversing the frontal zone, would influence the drift of planktonic organisms markedly, and convergence of currents could concentrate the plankton.

Temporally the observations showed a marked stability of frontal position, including the biology. Irrespectively of tidal excursions, we were not able to detect a deviation from the identified "peak" locality within the first 3 days of observation. After the additional 3 day-period we could, however, see a minor off-shelf movement of the front (5 nm). Other changes in hydrography was also observed at the last pass of the transect.

The observations of the field study, which are only preliminary described here, support other observations made during the field programme, and a picture is being drawn, in which the nursery areas of larval cod is tightly connected to frontal processes.

REFERENCES

Campana, SE, Smith, SJ, Hurley, PCF (1989) An age-structured index of cod larval drift and retention in the waters off southwest Nova Scotia. Rapp P-v Réun Cons int Explor Mer 191: 50-62

Ellertsen, B, Solemdal, P, Strømme, T, Sundby, S, Tilseth, S, Westgård, T(1981) Spawning period, transport and dispersal of eggs from the spawning area of arcto-norwegian cod (*Gadus morhua* L). Rapp P-v Réun Cons int Explor Mer 178: 260-267

Ellertsen, B, Fossum, P, Solemdal, P, Sundby, S (1989) Relation between temperature and survival of eggs and first feeding larvae of northeast Arctic cod (*Gadus morhua* L). Rapp P-v Réun Cons int Explor Mer 199: 209-219

Hurley, PCF, Campana, SE (1989) Distribution and abundance of haddock (*Melanogrammus aeglefinus*) and Atlantic cod (*Gadus morhua*) eggs and larvae in the waters off southwest Nova Scotia. Can J Fish Aquat Sci 46: 103-112

Lough, RG (1984) Larval fish trophodynamic studies on Georges Bank: sampling strategy and initial results. In: Dahl, E, Danielsen, DS, Moksness, E, Solemdal, P(eds) The propagation of cod Gadus Morhua L. Floedevigen rapportser1, Arendal, Norway, p395-434

Moors, CNK, Flagg, CN, Boicourt, WC (1978) Prograde and retrograde fronts. In: Bowman, MJ, Esaias, WE (eds) Oceanic fronts in coastal processes. Springer-Verlag, Berlin, p 43-58

Munk, P (1993) Describing the distribution and abundance of small 0-group cod using ring-net sampling and echo-integration. Comm Meet Int Coun Explor Sea CM-ICES 1993/G:40

Munk, P, Larsson, P.O, Danielsen, D, Moksness, E (1995). Larval and small juvenile cod (Gadus morhua) concentrated in the highly productive areas of a shelf break front. Mar Ecol Prog Ser (in press).

LEGENDS TO FIGURES

Figure 1.

Chart showing the position of sampling transect.

Figure 2.

Observations made during 1st pass of the transect 11/5 21:00 to 12/5 04:35. Note: 57.5 equals position 57°30'N.
Water density: Density in intervals of different shading as illustrated by the scale (<1027.0 to >1028.0 kg m-3 in intervals of 0.1).
Salinity: Salinity in intervals of different shading as illustrated by the scale (<34.5 to >35.0 o/oo in intervals of 0.1).
Temperature: Temperature in intervals of different shading as illustrated by the scale (<5.6°C to >8.4 °C in intervals of 0.2).
Currents: Direction of current illustrated by direction of arrow, relate to inserted compass card. Speed of currents indicated by length of arrow, 1 m/s = 4 cm.
Cod abundance: Estimated abundance of cod larvae in no m^{-2} illustrated by bars at sampling location.

Figure 3.

Observations made during 3rd pass of transect 12/5 21:50 to 13/5 04:24.
Same scales of illustrations as for Figure 2.

Figure 4.

Changes in surface (2 m depth) salinity during the different passes of transect. The symbols used for each pass are illustrated in the figure.

Figure 5.

Measurements of plankton abundance during passes of transect.
Macroplankton: Distribution at night and day is illustrated by the relative backscatter of a 38 Khz echo-sounder.
Calanus finmarchicus: Relative distribution illustrated by increasing darkness of shading, dots show sampling positions.
Pseudocalanus elongatus: Relative distribution illustrated by increasing darkness of shading, dots show sampling positions.
Cod larvae: Larval abundance measured during pass 3 inserted for comparison.

Map of investigation area
Transect of study indicated

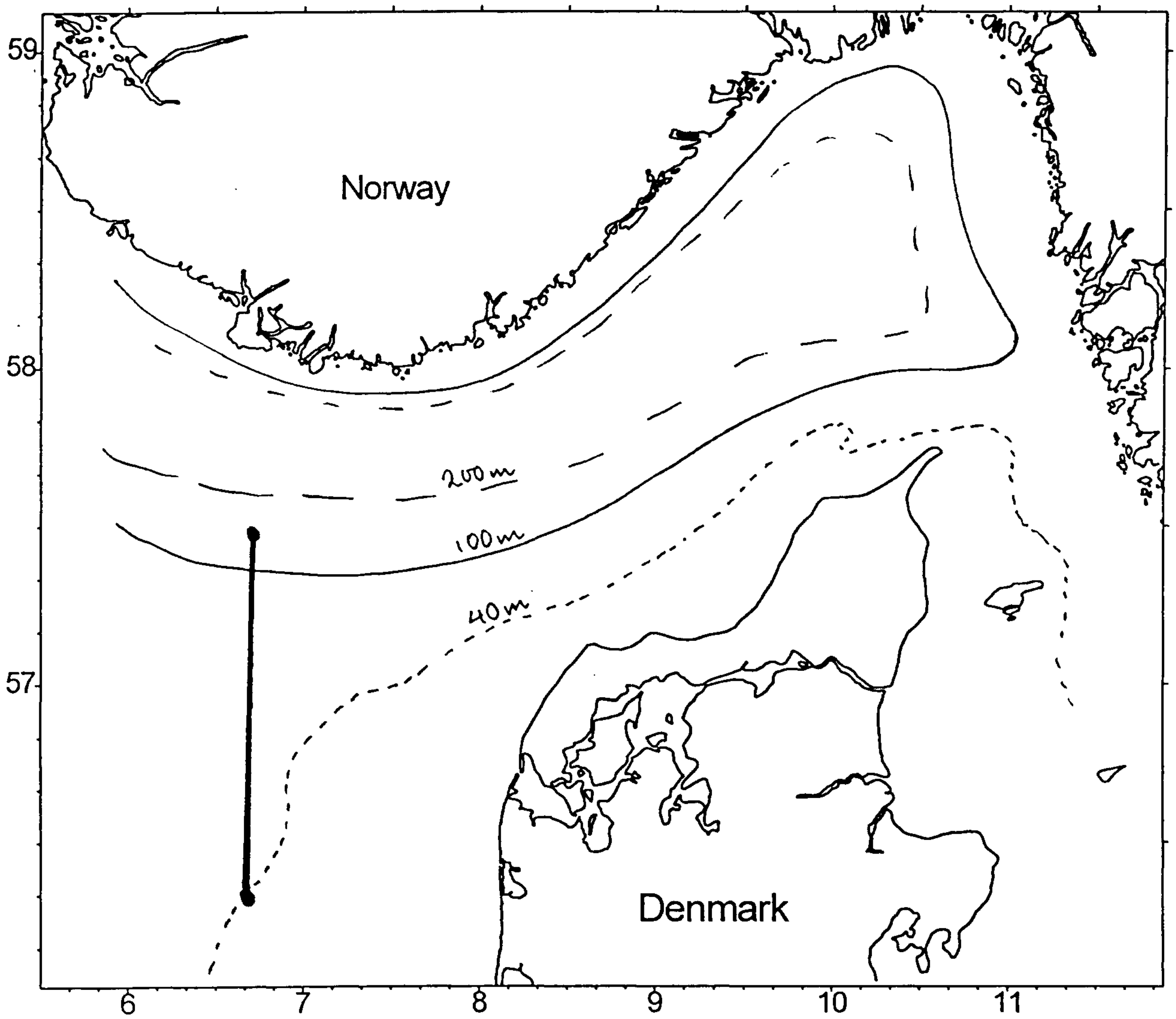


Figure 1

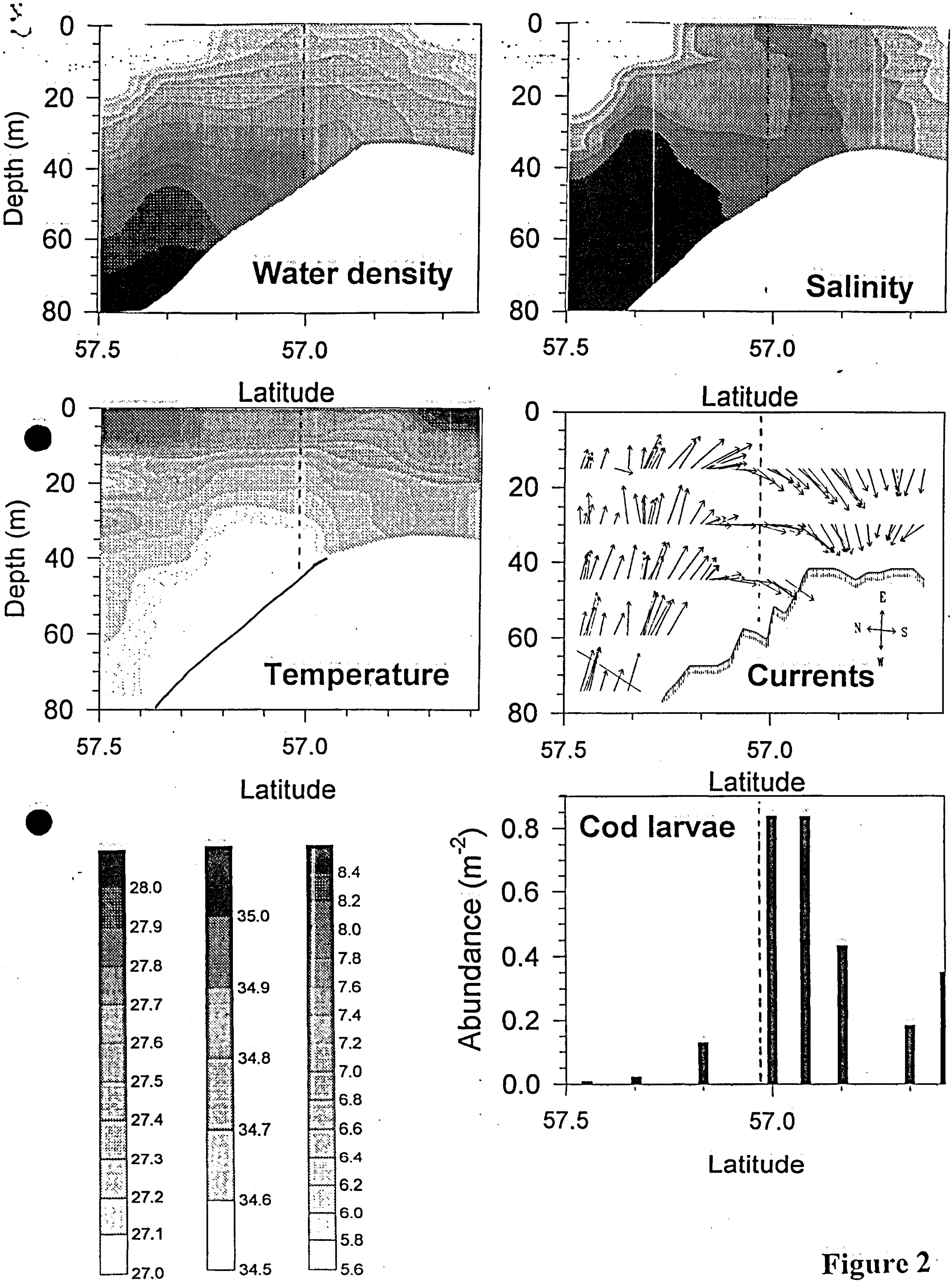
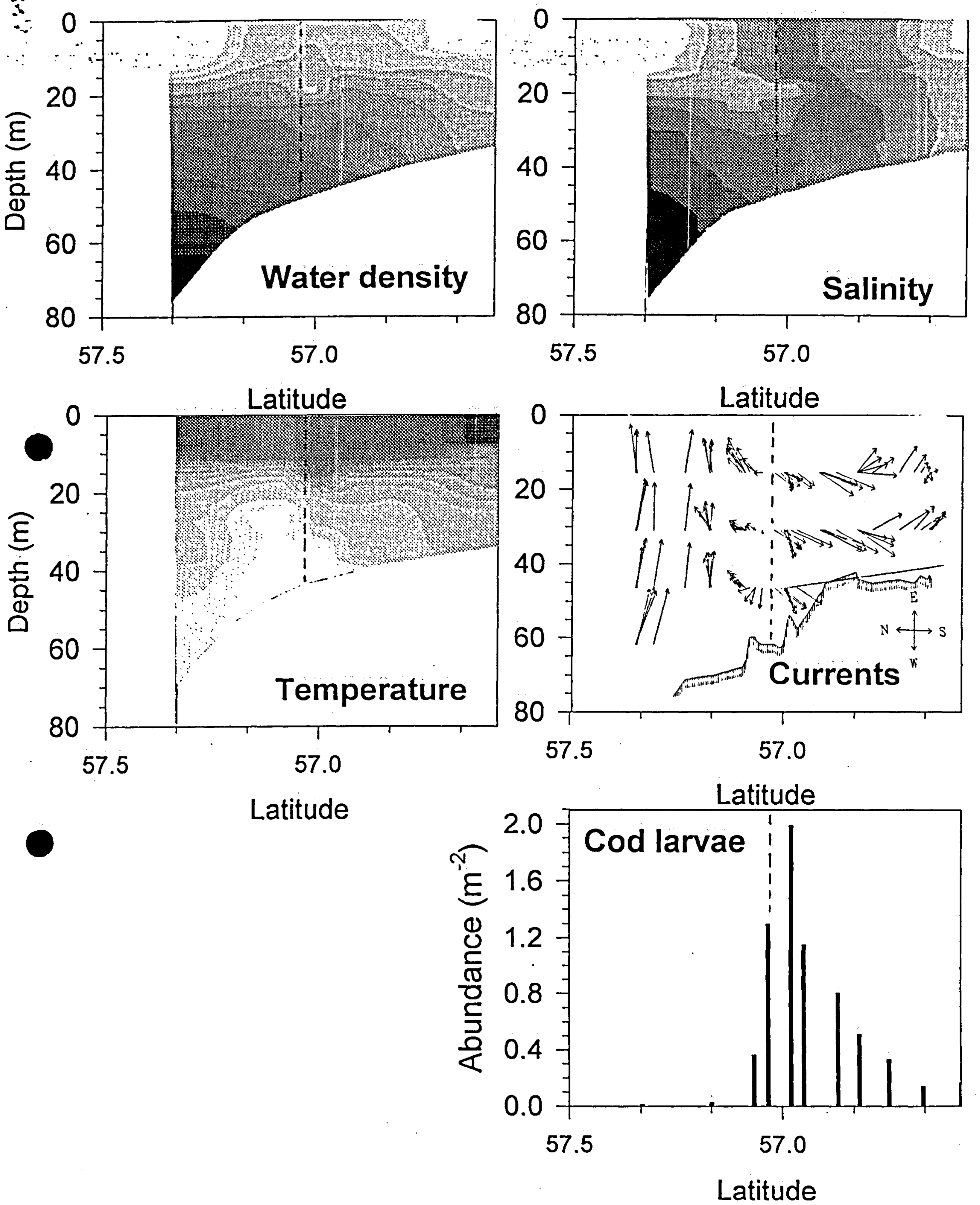

Water density
Salinity
Temperature
Currents
Cod larvae
Depth (m)
Latitude
Abundance (m^{-2})
N
S
E
W
0
20
40
60
80
57.5
57.0
0.0
0.2
0.4
0.6
0.8
28.0
27.9
27.8
27.7
27.6
27.5
27.4
27.3
27.2
27.1
27.0
35.0
34.9
34.8
34.7
34.6
34.5
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4
6.2
6.0
5.8
5.6

Figure 2



Water density
Salinity
Temperature
Currents
Cod larvae
Depth (m)
Abundance (m^{-2})
Latitude
N
S
E
W

Figure 3

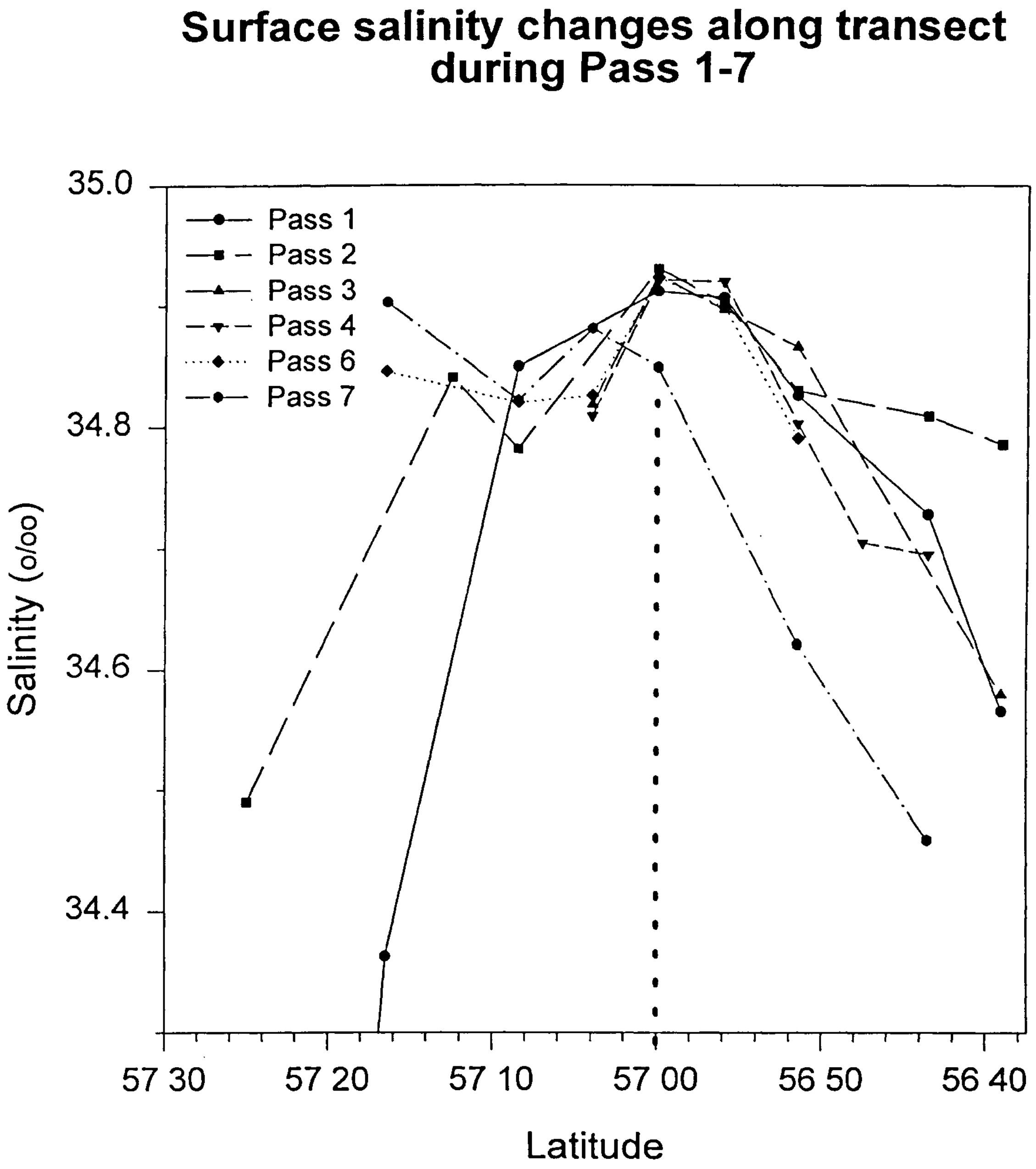

Surface salinity changes along transect
during Pass 1-7
35.0
34.8
34.6
34.4
Salinity (o/oo)
Pass 1
Pass 2
Pass 3
Pass 4
Pass 6
Pass 7
57 30
57 20
57 10
57 00
56 50
56 40
Latitude

Figure 4

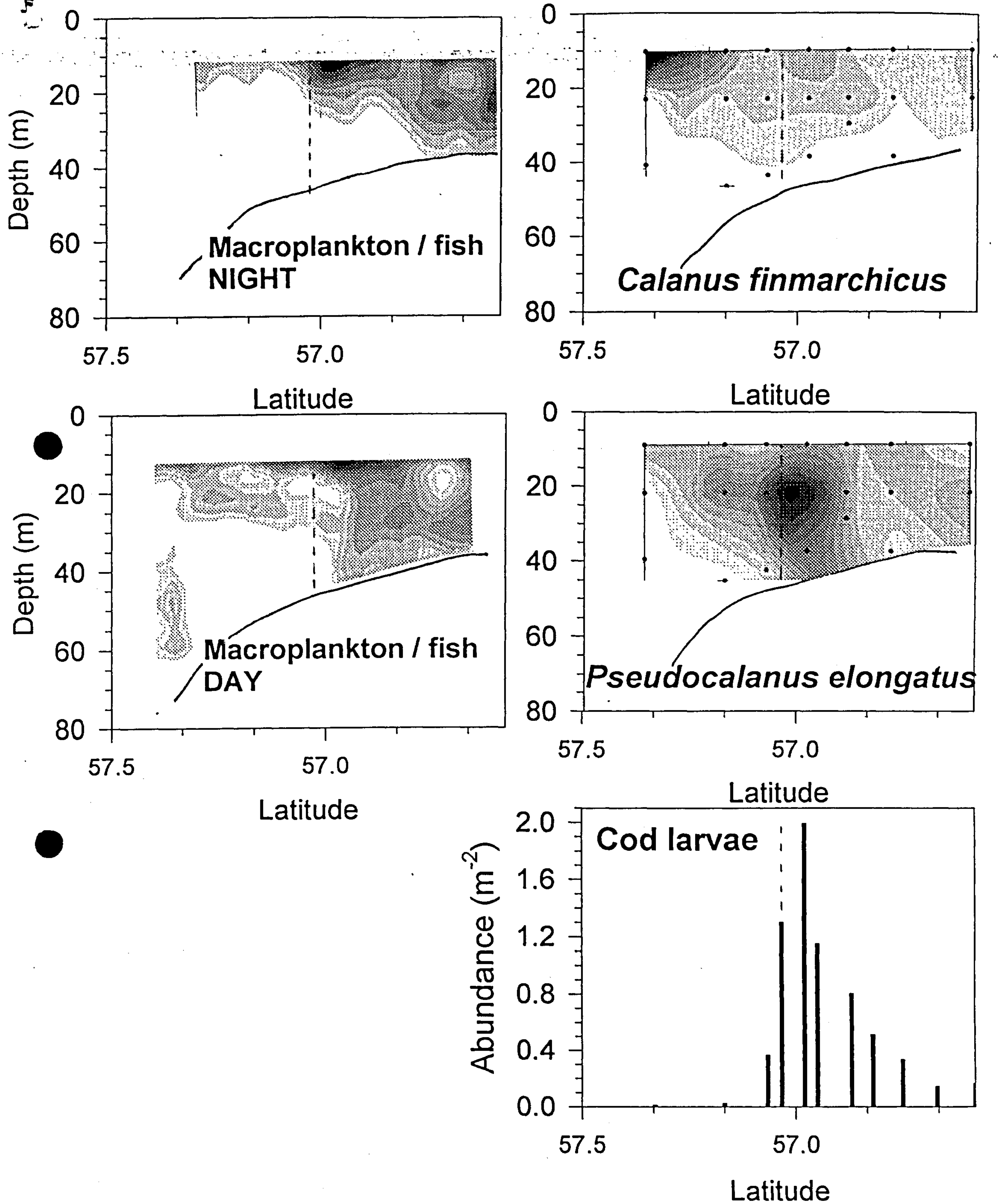

0
20
40
60
80
Depth (m)
57.5
57.0
Latitude
Macroplankton / fish
NIGHT
Calanus finmarchicus
Macroplankton / fish
DAY
Pseudocalanus elongatus
Cod larvae
Abundance (m-2)
2.0
1.6
1.2
0.8
0.4
0.0

Figure 5